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SANTA CLARA VALLEY WATER DISTRICT

ADOBE CREEK HYDROLOGY

AS A PART OF

THE HYDROLOGY OF ADOBE, MATADERO AND BARRON CREEKS

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PREFACE

In answering the questions about the hydrology of Adobe Creek, this report addresses the hydrologic analyses done in 1978 on Matadero, Adobe and Barron Creeks. It also discusses the stability of the findings of the 1978 study when compared with a statistical analysis of the data from Matadero Creek Gaging Station through the 1989 water year.

Home owners adjacent to the flood control project on Adobe Creek between Alma Street and Charleston Road have asked for a description of the District's hydrologic methods and analyses used to determine the extent of needed channel improvements. This report explains the District's hydrologic methods and provides a discussion of methods used by others. The report does not discuss the channel capacity and related hydraulic analyses.

PURPOSE OF THIS REPORT

The report has been prepared in response to requests by the public. The purposes of the report are to:

- Describe the District's hydrologic methods.
- Explain how the District's hydrologic methods were applied to the Adobe Creek flood control project.
- Provide an over-view of other methods to show how they compare with the District's.

SUMMARY

Following are some questions that have been commonly asked by the members of the public, together with answers that will clarify these complex hydrologic issues.

What is the issue?

The Santa Clara Valley Water District has determined that the existing Adobe Creek channel is inadequate to contain the 1% flood and therefore has planned a flood control project to mitigate that problem.

Some of the residents along Adobe Creek have expressed concerns about the channel improvements required, and have asked for a description and explanation of the District's hydrologic study (that is, the District's estimation of the amount of flood water to be accommodated by the Adobe Creek channel).

What is hydrology?

Hydrology is the science that deals with the circulation of water. Flood control hydrology is the science of estimating the magnitude of floods from watersheds and analyzing their frequency of occurrence. Flood waves (hydrographs) are described as having peaks and volumes. Flood control agencies throughout the nation use the 1% peak flow (flood) to design flood control channels, and the 1% flood volume to design flood basins, etc.

The 1% flood is that flood having a 1% chance of being equalled or exceeded in any year. The 1% flood has been adopted by the Federal Emergency Management Agency (FEMA), the United States Soil Conservation Service (SCS), the Corps of Engineers (COE) and most local flood control agencies as a design standard for flood protection measures.

Does the District's hydrologic method rely only on simple text book formulas and tables?

No. The District's hydrologic analyses of Adobe Creek and others includes complex hydrologic and statistical computer models. The intensive use of the District's hydrologic data base, together with these computer models, permitted the analysis and re-analysis of great amounts of data for many different design conditions. These are available for the public's inspection at any time.

Is hydrology an exact science?

No. It has many practical applications, such as flood control, which deal with natural processes that are random and ever-changing. Therefore, it's dependent on the laws of probability for the analysis of past data and the projection of future expected events and their chances of occurrence.

Some might say that the District's hydrology compounds the probabilities and results in high values. Is this true?

No. Although there is no hydrologic method that is immune to the possibility of compounding probabilities, all responsible hydrologists acknowledge that possibility and are careful to avoid producing results which have, in fact, a greater or lesser chance of occurring than 1% each year. The District has demonstrated that any such compounding in it's method is negligible.

Are there ways to verify the results of the study on Adobe Creek?

Yes. The data on the Matadero Creek USGS gaging station, together with 28 other gaging stations, were used in 1978 to develop the regional hydrology methods that are used at the present time. In addition, the Matadero Creek gaging station is also used to verify the site-specific application of the regional methods on both; Matadero Creek and Adobe Creek. The use of Matadero Creek data to infer information about the Adobe Creek design flows is an accepted procedure that is used throughout the profession. Those data represent the best available information in the area. In other words, the Matadero Creek gaging station was used as a guide and a measure of the applicability of the model to the Adobe Creek watershed in addition to the Matadero creek watershed.

To verify the design flows on Adobe Creek, an analysis of the data from Matadero Creek station, covering the period through 1989 was done. The results show that the design flows obtained in 1978 are still valid today, and the possibility of changing them due to new data (between 1978 and 1989) is very small (see Appendix II).

Do the District's hydrology methods conform to accepted standards in the field of professional engineering and flood control design?

Yes. As described in this report, the District -- along with several other flood control agencies -- has evaluated most of the models used in this field, and has chosen to use the methods used by all of the local, state and federal agencies. The District's hydrologic methods are considered to be state-of-the-art.

What is the effect of urbanizing the upper watershed on Adobe Creek?

The effect of urbanizing the watershed is a subject that is addressed in our hydrology study. Increased imperviousness and channelization are two major changes that take place as the result of urban growth. If rainfall is the inflow to an urban area, then the discharge through the gutters, storm drains and streets is the corresponding ouftflow. On the valley floor, where the land is relatively flat and stormdrains are designed for very frequent (small) floods (2 to 10 year floods), urbanization tends to retain the local design (large) floods in the urban area for a longer time thereby reducing the flows in the main flood control channels. In the foothills the effect of storm drains as a constriction is not seen. Urban growth in the upper watershed increases the flow in the main channel, especially if the land use density is high and the cumulative effects are accounted for.

The extent of urbanization of the Adobe Creek upper and lower watersheds was assumed, for the purpose of this study, to conform to the General Plans of the cities. Deviating from the General Plans could cause induced flooding. Those problem are site-specific, that should be addressed in the EIR processes associated with such deviations.

Is hydrology based on statistics and not real measurements?

Flood control hydrology is based on the statistical analysis of recorded natural processes (real measurements). Long term streamflow and precipitation data are some of the natural processes that are usually used in the analysis. The data are quantitative measurements of the behavior and the response of the designated watersheds.

It is understood that the error in defining the design value is 10% to 20%. With a margin of error like that how can one develop a confidence in the proposed project?

The flood control design values are, by definition, probabilistic events (1%, 10% flows etc.). Therefore, one has to depend on recorded data to define that event and its frequency of occurrence.

The error that is associated with that event is what statisticians call the "standard error of estimate". It is directly proportional to the variance of the data and inversely proportional to the number of years of record. In this area the number of years of record is usually less than fifty--a small sample when compared to the population of years spanning the life of any creek. Because of the size of such samples it is impossible to get an absolute value for the correct design flows. What one gets is an estimate of the design flow value with an associated standard error. The objective of a good study is to reduce the standard error of estimate. Using stochastic hydrology, the District has accomplished this objective by extending the recorded data to include information from adjacent stations.

BACKGROUND

To better understand the reliability of the District's hydrologic method, some background information is offered.

Hydrology

Hydrology is concerned with the study of the natural water cycle that begins with evaporation of water from the oceans and other bodies of water and continues with the formation of clouds, precipitation (rainfall) and then the complex distribution of that rainfall through evaporation, transpiration through plants and their leaves, infiltration into the ground, runoff into streams and major creeks and channels to the oceans where the description of the cycle began. Actually, the hydrologic cycle is much more complicated than this simplified characterization and is the target of a great deal of research and debate. An understanding of the hydrologic cycle must include consideration of the timing of various hydrologic events (lag time between precipitation stations, lag time between storm intensities and their corresponding runoff, etc.).

Flood control hydrology deals with one part of the larger hydrologic cycle - the estimation of flood flows and, more specifically, the estimation of the frequency with which a peak flow and volume of runoff of a given magnitude can be expected to be equalled or exceeded in any year. The aim of flood control hydrology is to improve the statistics (mean, variance, skewness, etc.) of floods that could be generated from a given watershed. For example, to design a flood control channel, engineers need to know the peak flow; that is, the maximum rate of runoff in cubic feet per second (abbreviated cfs) that could, on the average, be expected to be equalled or exceeded once in 100 years (said to have a 1% chance of being equalled or exceeded in any one year). Likewise, maximum volumes of rainfall runoff (expressed in acre-feet, abbreviated ac-ft; or in cfs-24 hours) and frequency of occurrence are desired for the design of other flood control facility, such as reservoirs, sediment basins and flood retention facilities.

Although peak flow and volume of runoff can be analyzed for any frequency of occurrence (say two-year, five-year, ten-year, twenty-year, etc., or 50%, 20%, 10% and 5% probabilities), the nationwide standard for flood control design was chosen -- based on economics -- to be the 100-year, or 1% flood.

A limited number of hydrologists assert that peak flows and maximum volumes are not related -- that these events are independent from each other. For floods in California, there is no question that peak flows are related to maximum volumes (cross correlation coefficient more than 0.90). Usually floods occur as a result of intense storms (storms that are usually cyclonic with large fronts). Therefore, we define the 1% flood to be that flood event having a 1% peak and a 1% volume. The question of compounding of probabilities is discussed later.

The Importance of Good Data

All hydrologic methods rely upon historical data. Streamflow records and rainfall records are essential to any analysis of floods and their frequency of occurrence. Depending on many factors, historical streamflow data at a certain location represent the actual response of the watershed to rainfall activity. Since our interest is in flooding, records of maximum annual streamflows are of more importance to the District than rainfall data.

> "It is recommended that rainfall data be given a secondary role... in Santa Clara County. Runoff data for about 40 stream gaging stations in the county and around it will produce much more reliable information on floods than the synthesis of precipitation data could yield". (Yevjevich and Simon, 1967, see Bibliography Ref. #1)

Inherent Errors

All historical records have inherent errors that must be dealt with during hydrologic studies:

- Normal Errors are those that exist because of the variability of natural events. All hydrologic methods are subject to these errors.

- Sampling Errors exist because of the deficiencies that result from trying to represent a large amount of data with only a limited sample. All hydrologic methods deal with this type of error.

- Man-made Errors come about because of the inadequacies of certain techniques in handling historical data or in creating data. One such technique which can bias its results is to "simulate" streamflow data by attempting to model the relationship between rainfall and runoff. Such synthetic data are particularly subject to biases that can render the results useless, especially in the case of extreme (flood causing) events.

In relying upon historical records of streamflow and precipitation, great care is taken to ensure the quality of those historical data. While there may be many private, unpublished records kept by individuals, these cannot be used without further assurances that the data were collected in a manner consistent with standards of scientific data collection. Data published by responsible data collection agencies are usually collected by qualified individuals and, by publication, are subject to further scrutiny by the professional community. It is safer for hydrologists to use such data rather than data obtained from private collectors. The State of California Department of Water Resources (DWR) and the United States Geological Survey (USGS) publish precipitation and streamflow records. The Santa Clara Valley Water District is a contributing agency in these data collection publishing programs.

Gaged Watersheds

Many streams in Santa Clara County have recording stream gages at various locations. Also, a network of over 100 precipitation stations in Santa Clara County automatically record rainfall and provide a long, historical record. Many other streamflow and precipitation stations outside of Santa Clara County - but within the immediate hydrometeorologic (weather) area - complement the District's in-county data network.

Ungaged Watersheds

Many streams and watersheds do not have historical streamflow records. In order to have hydrological data that can be used for flood control design in these ungaged watersheds, some method must be used to estimate peak flows and volumes without benefit of data specific to the watershed. This problem must be addressed regardless of which of the several hydrologic methods is used (a discussion of the various hydrologic methods follows). Nor do all streams and watersheds with precipitation gages and/or stream gages have records that are entirely continuous over the life of the gage. Various circumstances occur during the life of hydrologic gaging devices that can interrupt the data collection process. Such periods can last for hours, days, weeks or even months.

Synthetic Data

To enhance historical streamflow records, that is, to develop synthetic data, hydrologists use some form of mathematical modeling. The District uses such mathematical (stochastic) techniques for "filling in" missing data, or for extending short records of data on gaged streams using longer historical streamflow records of adjoining streams and watersheds. This "filling in" process permits longer and more continuous records to be made available without sacrificing the statistical quality of the data. Such stochastic data are what statisticians consider "random, continuous and homogeneous and with a known standard error of estimate" - qualities that permit further rigorous statistical analyses.

Some hydrologists use computer techniques to "simulate" missing streamflow data using rainfall data. Rather than using information from adjoining streamflow stations, the process of "simulating" data attempts to model the continuous and, hence, extremely complex relationship between rainfall and runoff. In such models, many human judgement factors enter into the process. For example, some natural processes, such as the area-wide distribution of rainfall, are quite variable over a period of time. Nonetheless, simulation models such as the Stanford Watershed Model are most sensitive to rainfall. The results of such modeling can therefore be biased because of the many assumptions that are needed, such as the assumption of constant rainfall distribution.

Hydrologic Methods

As there is more than one opinion on the "best" way to handle the problems of incomplete historical records and ungaged watersheds, there is also more than one opinion on the "best" hydrologic method to estimate runoff peaks and volumes. In fact, some methods are adequate for some engineering applications but not for others.

If there is a consensus at all, it is that for gaged watersheds - that is, for watersheds that have long records of streamflow - there is no better method for deriving design peak flows and design volumes than by the statistical analysis of the historical record - checked if possible against the statistical data from any nearby watershed - and further checked against statistical data for the general region applied to the particular watershed. This is standard practice for the Santa Clara Valley Water District and, with some variation, for the majority of flood control agencies.

However, since most watersheds are not adequately gaged, or are not gaged at all, different points of view among hydrologists arise with regard to analysis of ungaged watersheds.

At the turn of the century, hydrologists began using simple statistical and mathematical tools (such as the rational formula described below, and straight-line projections). As more recorded data become available, scientists and mathematicians became more involved in seeking the best use of the data and quickly many new techniques evolved (various frequency distributions, different interpretations of rainfall and runoff relationships and the movement of resultant flood waves over land). As a result, hydrologists across the nation started using these techniques, each based on his own background. This generated inconsistent results, and controversies started. In the late 1960's and early 1970's, the federal government recognized the problem of inconsistent interpretation of hydrologic events and decided to adopt a standard hydrologic method. This was needed for the administration of the National Flood Insurance Program which was in the final stages of nationwide adoption.

The result of the federal efforts in arriving at a national consensus on hydrologic method was the publication of a unifying document - Bulletin #17, Guidelines for Determining Flood Flow Frequency - by the President's Water Resources Council (WRC). Most hydrologists accepted the document and its recommendations.

In the 1970's, the National Flood Insurance Program was fully implemented. The WRC Bulletin #17 in combination with the Corps of Engineers unit hydrograph technique (described later in this report) were found to have a unifying effect and were, therefore, used by the Flood Insurance Administration for its flood mapping program.

As the National Flood Insurance Program applied the above-described techniques, most flood control agencies adopted these same hydrologic methods for estimating peak flows and runoff volumes. The Santa Clara Valley Water District was the foremost user of those techniques and improved upon them by use of stochastic methods for augmenting the relatively short historical stream gage record at some of the District's stations.

There are several approaches to hydrology in use today by flood control and storm drainage agencies and design firms:

Empirical Method ("Rational Formula")

This is a method for estimating peak runoff and is only suitable for watersheds of extremely small size (perhaps several acres) of uniform surface, such as paved parking lots or city streets. It is no longer applied realistically to large, complex watersheds that have rural as well as urban characteristics.

Statistical (Stochastic) Method

This method involves the statistical analysis of historical streamflow and rainfall data (runoff peaks and volumes). As with other methods, the desired results are reliable estimates of 1% (100-year) peak flows and the associated volume of runoff. The backbone of this hydrologic method is the comprehensive mathematical (stochastic) analysis of historic streamflow data. It includes nationally recommended techniques to expand on the historical record and to fill in missing data by using mathematical modeling. Based on the resultant historic and stochastic data, final estimates of design peak flows and volumes can be analyzed by standard statistical procedures. The standard error of estimate (or equivalent number of years) of the design flows can be determined and used to define the goodness of the estimated values.

Deterministic Methods (Continuous Modeling)

Deterministic hydrologic methods attempt to model the continuous and complex relationship between rainfall and runoff. One such deterministic program is the Stanford Watershed Model (SWM) developed in the early 1960's. Continuous modeling is proving useful for analyses of pollutant discharge volumes and, to a limited extent, for flood warning systems. However, to date, it appears that SWM does not lend itself to flood control design for reasons that will be explained.

The idea of continuous modeling is to describe the continuous long term rainfall-runoff relationship using mathematical formulas and functions that try to account for all rainfall once it lands on the surface of the watershed until it passes through the maze of complex paths that water can take after that time. Through an accounting procedure, estimates are made of the runoff that makes its way to the major flood carrying watercourses. The computer model is "calibrated" against a small part of the available historical data for the watershed. If the watershed has no data, then the model is calibrated against the nearest available historical data from some adjoining watershed. The calibrated model is used to generate "simulated" runoff data for periods longer than the period of calibration.

The District's method, described below, results in the description of a single flood wave with a specific peak flow, volume, shape and frequency of occurrence. Continuous simulation, however, results in the generation of a continuous time-series of peaks, volumes, etc. Statistical analyses of such continuous series would generate design values (peaks, volumes, water surface elevations, etc.), but without a common denominator that relates these design values to each other. In simulation, it is claimed that design flood volumes do not coincide/correlate with design flood peaks, and that the total design flood does not have the same probability as that of peaks and volumes regardless of the magnitude and intensity of the storm. Such claims are not supported by the data analyzed by the District, where cross correlation of peaks and volume are higher than .90, a good indication of direct dependency.

Continuous models are made to manage large quantities of input rainfall data to "perform deterministic simulation of a variety of aquatic processes" (R. K. Linsley). As a result, deterministic data -- or data that could be reproduced given the same input values -- are obtained and are treated as purely random events. It is not clear how much randomness is left in this type of data. Also, it is not clear whether the contemporary laws of statistics apply to such results and, if they do, under what conditions and limitations.

THE DISTRICT'S HYDROLOGIC METHOD

The District's hydrologic method has evolved over many years into a procedure that has achieved the endorsement of nationally and internationally respected hydrologists. It is a statistical method similar to that in use by the majority of flood control agencies nationwide. A panel of nationally recognized hydrologists reviewed the District's method in 1976 and recommended that it be disseminated to other flood control agencies for possible adoption as a national standard.*

The method relies primarily upon historical local as well as regional streamflow data and secondarily upon rainfall data. Santa Clara County is fortunate in having many years of streamflow and rainfall data collected at over one hundred gages under a highly competent data collection program. In addition to the District-maintained hydrologic gage network, there are several gaging stations owned and operated by the United States Geological Survey (USGS), and others.

> "The secondary role of precipitation means only that the rainfall data, with its more accurate properties (say annual or seasonal values) should be used" for estimation of parameters of flood frequency distributions on ungaged watersheds (Yevjevich and Simon, 1967)

With the above as background, the following is a general description of the District's hydrologiclc method. A more technical description of the method is available from the District upon request.

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*The panel, and their affiliations in 1976, were: Professor Leo R. Beard, University of Texas; David R. Dowdy, U. S. Geological Survey; Professor Neil S. Grigg, Colorado State University; Professor L. Douglas James, Georgia Institute of Technology; Professor V. Yevjevich, Colorado State University.

Three Cross-Checking Techniques

The District uses a statistical method as described in the previous section on general methods. Rather than relying on a single statistical analysis, the District utilizes three independent techniques that derive comparative results (design peak flows and maximum volumes). Those three independent techniques are:

1. An analysis of the rainfall/runoff relationship for the watershed (unit hydrograph analysis). Sample results from this analysis are:
   1% peak flow (1)
   1% runoff volume (1)

2. A statistical analysis of historical stream gage records in the watershed of the facility being designed. Sample results from this analysis are:
   1% peak flow (2)
   1% runoff volume (2)

3. A regressive analysis of historical streamgage records of streams in the surrounding area (regional flood frequency analysis) as applied to the watershed in question. Sample results from this analysis are:
   1% peak flows (3)
   1% runoff volume (3)

The results of the three independent analyses are compared. In fact, the three sets of results can each be given a numerical weighting factor equal to the calculated standard error of estimate, and the finally selected 1% peak flow and 1% volume can, if appropriate, be computed as the weighted average of each of the three results. In some cases the use of a weighted average is not recommended, and rather, one of the three sets of results might be selected for design.

It should be noted that the District's hydrologic method could accommodate a fourth, fifth, sixth, etc. technique in addition to the present three if the additional techniques were to be statistical in nature - that is, if they were each to have a computable standard error of estimate as normally considered by statisticians. To date, there are no other such techniques beyond those used by the District.

The District's three techniques are shown in a block diagram presented in Appendix I.

Compounding Probabilities

As previously explained, flood control agencies usually design and construct flood control measures to contain the 1% (100-year) flood. Floods can be grouped according to any frequency of occurrence - annual floods, 10-year floods, 20-year floods, 50-year, 100-year, 200-year, 300-year, 1000-year, etc. The 100-year, 1% flood is the common standard that has been accepted for design of flood control facilities. Hydrologists, when they produce estimates of floods, are careful that their results actually do have a 1% chance of happening in any year; otherwise the accepted 1% standard may not be achieved. Probabilities of the individual components of floods must be considered so that the end product has a probability of 1%.

Since all hydrologic methods deal with the statistics of flood events, there is always the possibility of inadvertent compounding of probabilities. This is a subject that hydrologists seem to like to bring up when confronted with differences of opinion - especially when the disagreing parties subscribe to different hydrologic schools (the "stochastic school" versus the "deterministic school", for example). If a hydrologist considers that the probability of occurrence of each of two assumably unrelated factors -- such as peak flows and volumes -- is one in one hundred (a .01, or 1% chance of each of them occurring), then actually he may have recommended a design flood that has a probability of occurrence of one in ten thousand (.01 multiplied by .01), rather than one in one hundred.

However, if two events are dependent - that is, two phenomena of nature whose individual behaviors are directly related to each other - then, there is no compounding of probabilities, especially when statistical analysis shows the cross correlation between the two events to be very high.

The criterion in these cases is that if the correlation coefficient between peaks and volumes is less than 0.9, then it may be said that their coincidence is less probable and some compounding of probabilities is likely. For Matadero Creek, the computed correlation coefficient between peaks and volumes is 0.942 for the recorded data alone and 0.964 for recorded data combined with derived (reconstituted) data. Therefore, there is no question that peaks and volumes are highly correlated and that the compounding of probabilities in the resultant flood is not significant. The combination of the probability of peaks and volumes can safely be assumed to be equal to the probability of the resultant flood. This is because floods are caused by extreme storm events with periods of intense rainfall. Such storms are frequent in this geographical area. Intense storms with small volumes of runoff are usually characteristic of arid (desert) areas and not Santa Clara County.

"Because the individual peaks and volumes are highly correlated, the effect of considering joint probability may change the resultant probability very little". (1976 Panel Report,page 35, Bibliography Reference #2.)

Because the District's computed cross correlations are in fact less than 1, it is understood that some extremely small amount of compounding of probabilities could occur. For that matter, no hydrologic method used today is immune to the possibility of compounding of probabilities. This is especially the case with methods that attempt to transform rainfall records to runoff records at various locations by assuming that the coincidence of timing of rainfall and all other parameters is extremely probable.

In fact, the very small amount of compounding of probability in the Districts method is further reduced by using peak flows to design flood control channels, and flood volumes to design storage facilities, but never peaks and volumes together.

Because of the reasons described above -- that is, the high correlation between peak flow and maximum volume and the fact that there is no need to combine peak flows and maximum volumes to design water structures -- the possibility of compounding probabilities in the District's method is negligible.

The District's Analyses

The District has calculated 1%, or 100-year, peak flows and their related runoff volumes for the watersheds of Adobe Creek, Matadero Creek and Barron Creek. The results of that study are documented in the District's 1978 report Hydrology Documentation for the Northwest Flood Control Zone. That report, and several others available at the District office, provide more detailed information.

The first part of the District method employs the unit hydrograph technique (as presented in the Corps Of Engineers HEC-1 program) to convert a design storm to a corresponding flood. Based on that a generalized hydrologic model is built that simulates the response of each of the three watersheds (Adobe, Matadero and Barron) to design storms. The inputs to such a model are:

- The synthetic unit hydrograph parameters that were generated for each sub-watershed of the three creeks.
- The storm volume, its duration and the frequency of occurrence as developed from the analysis of the long term rainfall data in and around the watershed.
- The areas of watersheds or sub-watersheds, slope, antecedent flood conditions and the recession characteristics as well as the loss rate functions.

The output hydrographs from such a rainfall/runoff model have peaks and volume that represent the application of the deterministic (single storm) part of the District's hydrology method.

Of the three creeks, only Matadero Creek is instrumented with a gaging station that has a long historical record of streamflows and volumes. The newly constructed gage at Adobe Creek (constructed in 1987) is not mature and is of no value for statistical analysis at the present time. For this reason the record from Matadero gaging station was used to verify the results of the hydrologic rainfall-runoff model discussed above. Such verification (calibration) of the model on the gaged Matadero location will permit the use of this model on the Adobe Creek watershed (an ungaged watershed).

At the Matadero Creek gaged location near El Camino Real, design peak flows and corresponding volumes were calculated using the three separate techniques described previously. The results of those analyses are described as follows:

1. Rainfall/Runoff Analysis

The first independent analysis by the District dealing with rainfall-runoff transformation, as discussed above, was used to generate independent estimates of peak flows and volumes on Matadero Creek at the gage location near El Camino Real.

The results of the unit hydrograph analysis for the 1% flood on Matadero Creek are shown on Figures 1 and 3 as points on the frequency lines. The 1% peak and volume so determined are:

Peak Flow:	2091 cfs
Volume:	24-hour volume = 909 cfs-24 hours (which is equivalent to 1,800 acre-feet or about 4.5 inches of excess rainfall).

2. Statistical Analysis of the Matadero Creek Stream Gage Records

Analyses of the streamflow data at the Matadero Creek gage are shown on the following graphs. Figures 1 and 2 show how the actual historical and derived (stochastically reconstituted) peak flows and historical and reconstructed volumes (dotted points) rank with respect to frequency of occurrence. The solid lines through the data points in the two graphs have been plotted using the recommended technique of the United States Water Resources Council, 1976. In Figure 1, the broken heavy line shows the design condition and reflects the effects of urbanization which can, because of the proliferation of paving, roof tops and other impervious surfaces, act to increase runoff. That effect is more pronounced for frequent flood events (left end of the graph) and less pronounced for less frequent flood events (right end of the graph).

Figure 2 shows the dramatic differences that can result if the maximum 24-hour volumes (appropriate for design) are plotted against the maximum _daily_ (calendar day) volumes (inappropriate for design). The District analyses utilize 24-hour volumes.

Figure 3 shows the design 24-hour volume (heavy broken line) compared to the historical record. Notice the effect that urbanization has on increasing runoff volumes as shown by the line labeled "urbanization'.

The District's analysis of the Matadero Creek stream gage records gives the following estimate of the 1% peak flow and corresponding volume (Figures 1 and 2):

Peak Flow: 2310 cfs (the District's 1978 Northwest Zone report inadvertently reports this as 2170 cfs due to a typographical error).

Volume : Daily volume (calendar day) = 560 cfs-days (which equates to 1,108 acre-feet of volume or about 2.8 inches of excess rainfall).
24-hour volume = 710 cfs-24 hours (which equates to 1,405 acre-feet of volume or about 3.7 inches of excess rainfall).

MATADERO CREEK STREAM GAGE
Near El Camino Real
PEAK FLOWS

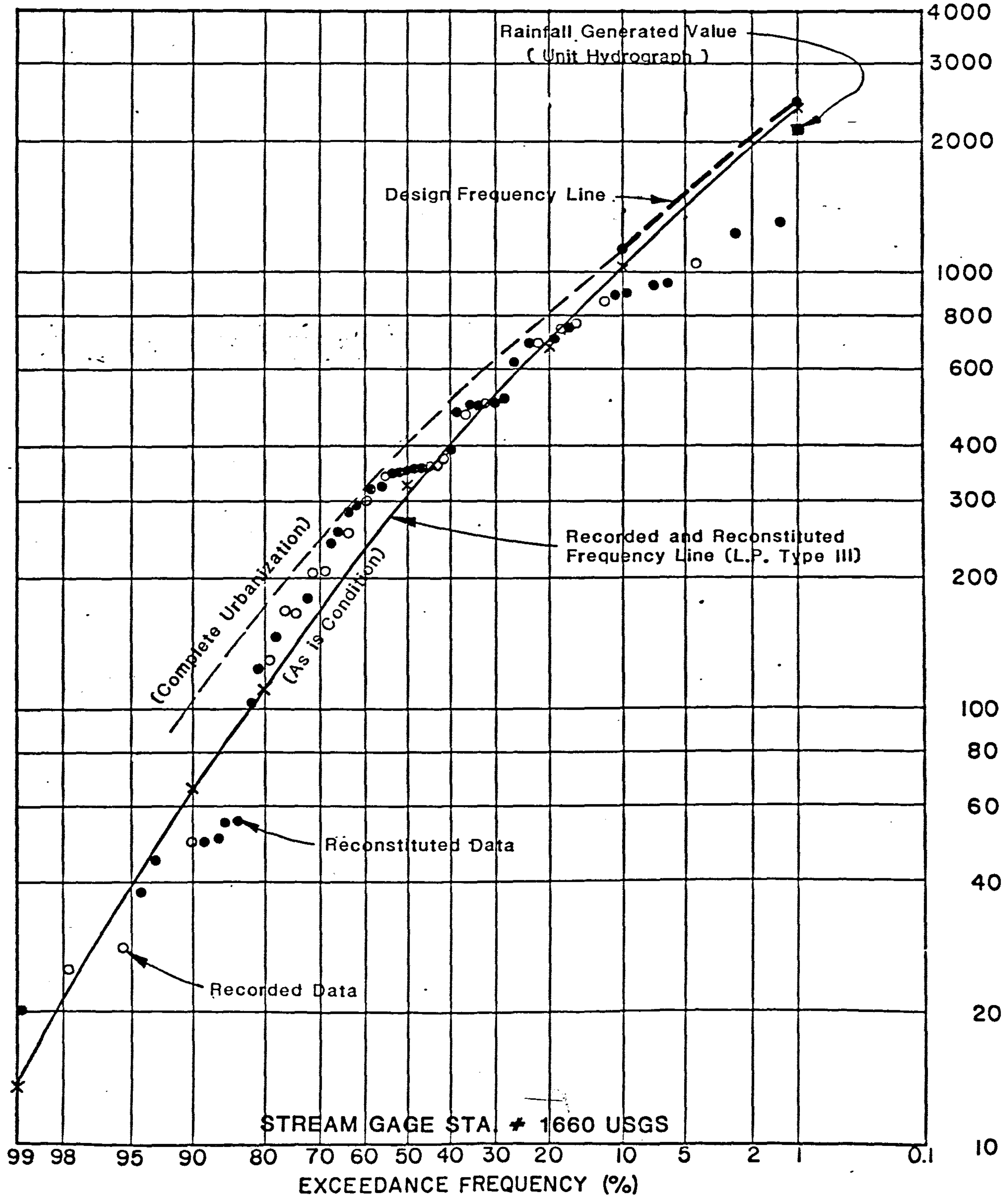


FIGURE 1

MATADERO CREEK STREAM GAGE

Near El Camino Real

(Comparison Of Daily Vs. 24-Hr Volume)

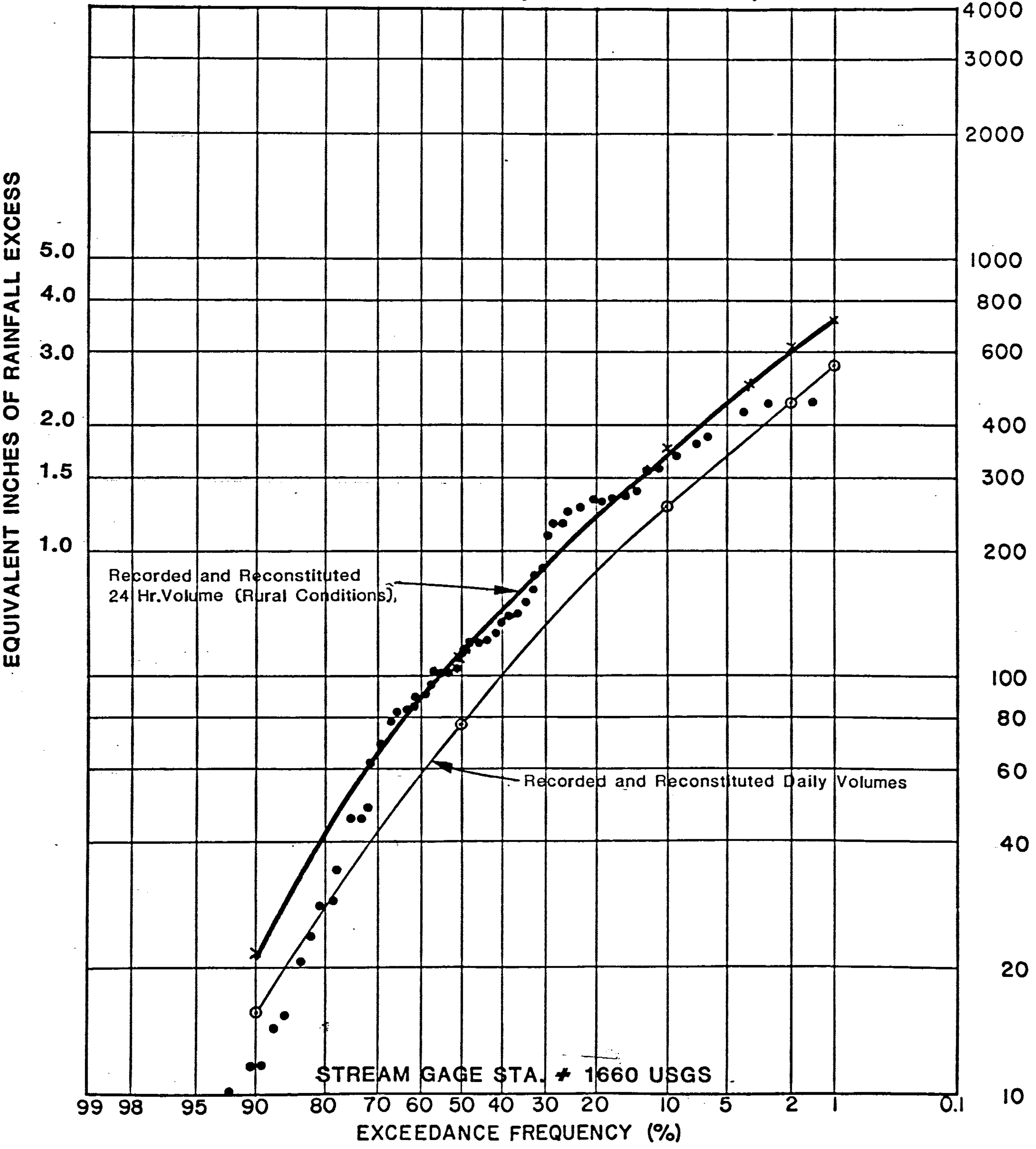


FIGURE 2

MATADERO CREEK STREAM GAGE

Near El Camino Real

(Design Volumes)

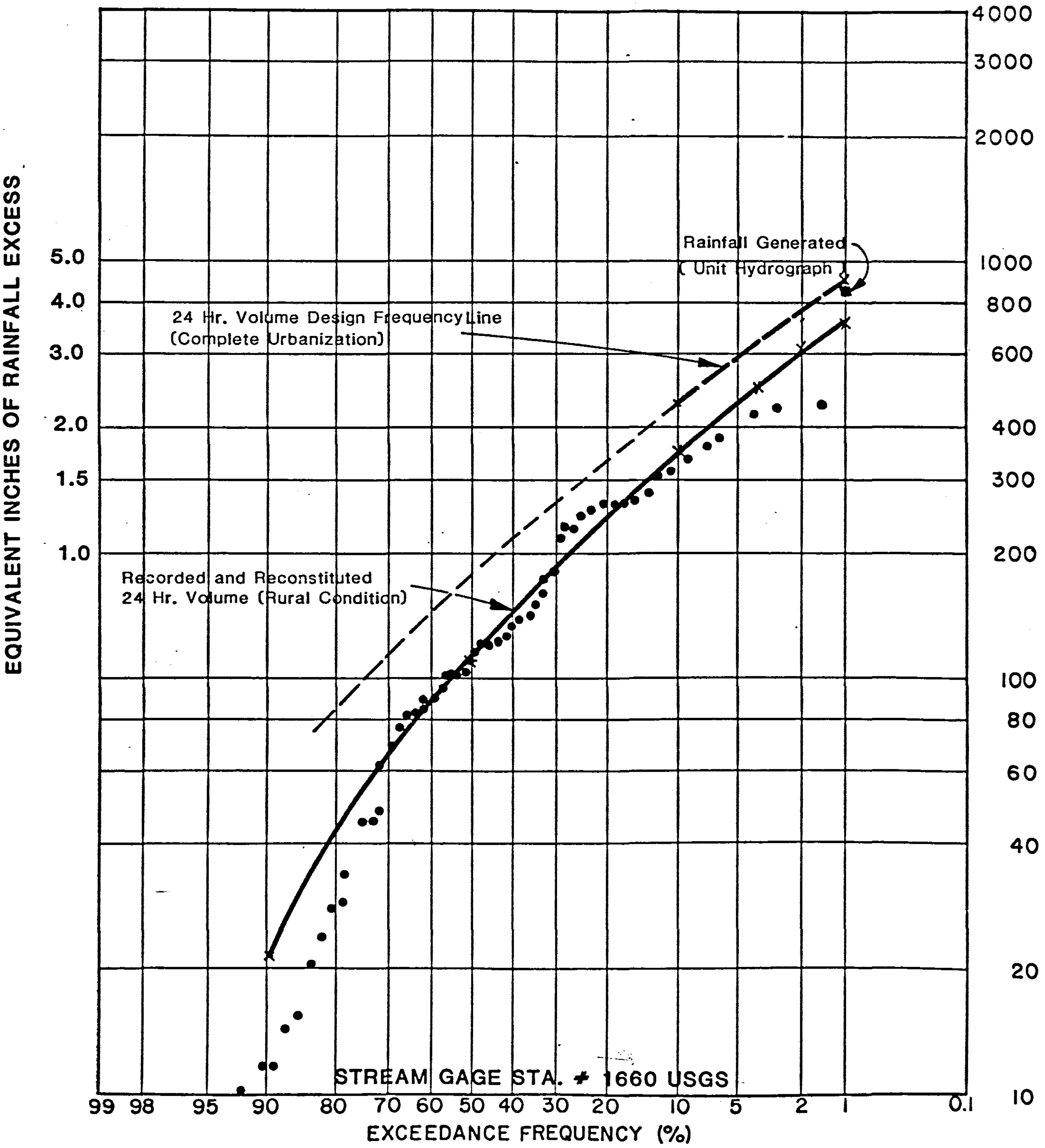


FIGURE 3

3. Regional Flood Frequency Analysis

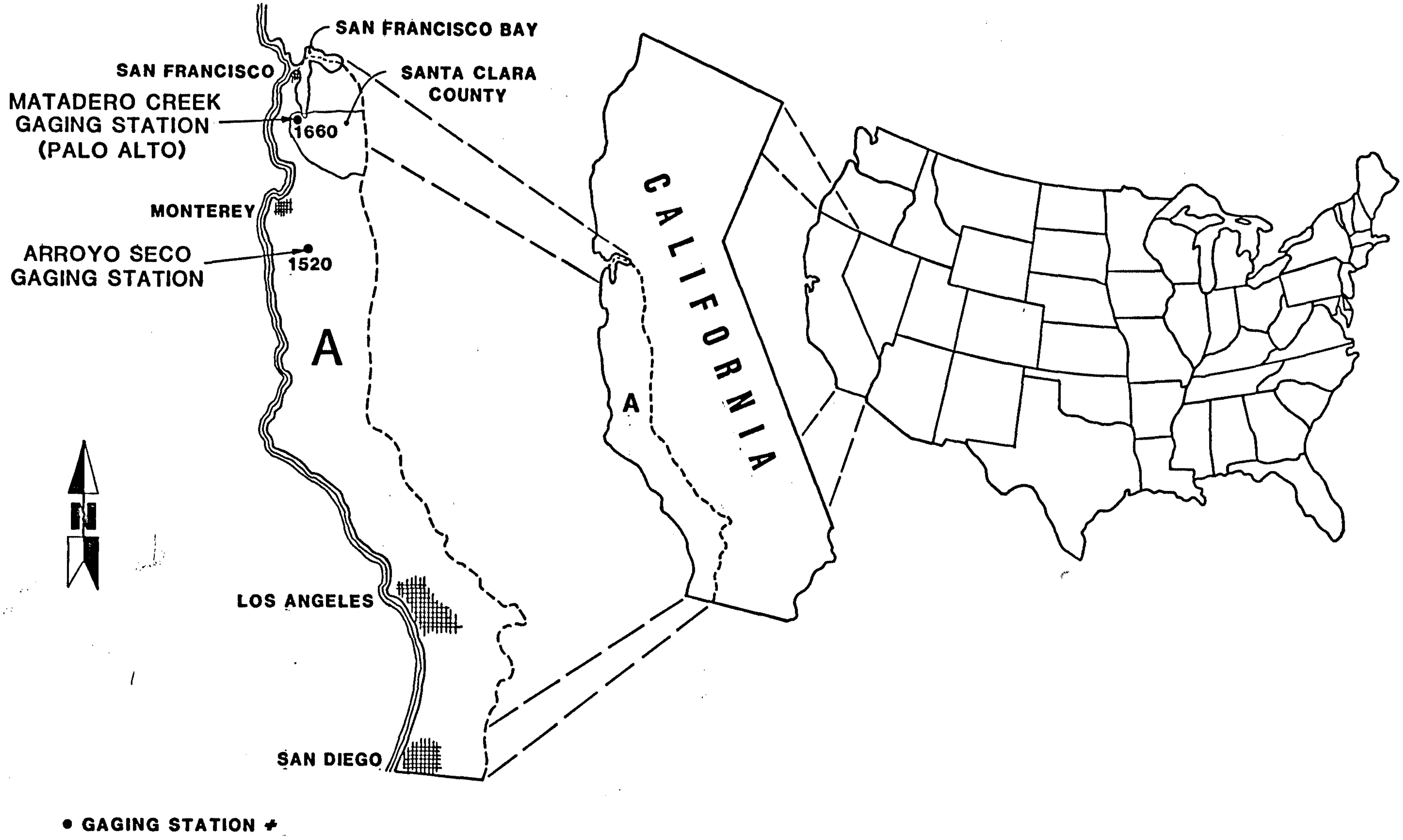
The third comparison technique used by the District is an analysis of the historical streamflow data at the Matadero Creek streamgage compared to data from the immediate hydrometeorological region - that is, the area encompassing Santa Clara County and some surrounding areas which are considered subject to similar storm patterns. This regional analysis permits comparison of the Matadero Creek streamflow record with the streamflow records of gages representing most watersheds in the region. Some 30 such stations were compared for this regional analysis.

One streamflow station in the region with a very long record is on Arroyo Seco Creek, a tributary of the Salinas River south of Salinas. This station has over 100 years of good record and the information in that record is considered to be the most valuable information in any hydrologic study of the region. The Arroyo Seco station is considered by the United States Geological Survey (USGS) and the United States Corps of Engineers (Corps) to be within the same hydrometeorologic region (Region A) as other stations in Santa Clara County, as shown on Figure 4, and was therefore analyzed along with approximately 29 other stations.

The results of this regional analysis are two sets of regional regression equations. One relates the statistics of the peak flows to the mean annual precipitation, watershed area, slope and length of creeks, etc. The other set relates the statistics of the runoff volumes (24-hour, 1-day, 2-day and 3-day) to those same watershed characteristics. The District's regional regression equations are updated (if necessary) as more years of hydrologic data are gathered (every ten to fifteen years). The equations are currently listed in the District's 1976 report, Development of Regional Regression Equations. The report is available from the District upon request.

At the Matadero Creek stream gage location, the 1% flood and volumes that resulted from the application the regional regression equations are as follows (refer to Figure 1 for peak flows and Figure 3 for volumes):

Peak flow :	2369 cfs
Volume :	24-hour volume = 912 cfs-24 hours which is equivalent to 1,800 acre-feet or 4.5 inches of excess rainfall. (At the Palo Alto Flood Basin, 4.5 inches of excess rainfall volume is equivalent to 6,600 acre-feet from the three contributing watershed.)



MAP OF PACIFIC SLOPE BASINS IN CALIFORNIA SHOWING GAGING STATIONS AND FLOOD FREQUENCY REGION A

FIGURE 4

The 4.5 inches of excess rainfall noted above is not a unique or remote event. Such rainfall could come from a 1% storm with approximately 6.5 inches of total 24-hour rainfall. For comparison, the 1% 24-hour storm within this area ranges from 4.2 inches at Santa Clara University to 7.7 inches at Dahl Ranch to 8.5 inches at Stevens Creek and as high as 13.82 inches at Saratoga Gap, at the top of the Santa Cruz Mountains (Reference is made to the State Department of Water Resources Bulletin #195). These are offered as supporting evidence that the 6.5 inches of average rainfall from a 1% storm over the Adobe, Barron, and Matadero Creeks watersheds is very realistic.

Final Design Flood Flow Value

The final design flow (2369 cfs) adopted for the Matadero Creek gage location is based on the application of the regional regression equations. This value is close to the weighted flow value obtained from the rainfall/runoff analyses, the statistical analyses and the application of the regional regression equations as shown above.

Table 1 is a summary of the results of these three independent techniques. It shows a very close agreement among the results as compared to the weighted average and, therefore, the results of the regional analysis were selected for use in designing the flood control projects on Adobe, Matadero and Barron Creeks.

Tables 2 and 3 show the final design flows on the three creeks including the flows on Adobe Creek. Those values were obtained from the application of the unit hydrograph model (discussed above) to the three watersheds to generate peaks and volumes. Using the results of the regional regression analysis at each location, those peaks and volumes were balanced and the resultant balanced (design flood) flows are routed downstream.

In urban areas the study included the application of the urban hydrology methods (discussed in Ref. 8) which were used to determine flood flows from the pervious and impervious parts of the developed urban areas within the designated watersheds. This entailed an intensive study of storm drain systems and land uses in order to understand the effect of these urban features on the rate and timing of runoff.

On Adobe Creek Table 2 shows that the 1% flow up stream of Barron (start of project), is 3080 cfs (rounded up to

3100 cfs). The corresponding area is equal to 10.84 square miles. This give a unit value of 285 cfs per square mile--a very reasonable value when compared to the unit values on other lacations in the area (280 on Barron, 312 on Matadero).

Similarly, Table 3 shows that the 10% flow in Adobe at the same location is 1822 cfs.

For more information about the detailed hydrologic calculations used to generate tables 2 and 3 please refer to Northwest Flood Control Zone Hydrology Report (Bibliography # 3).

TABLE 1

SUMMARY OF DISTRICT FLOW VALUES
MATADERO CREEK @ USGS #1660

		1% Peak Flow c.f.s.	1%-24 Hr. Volume c.f.s.-24 Hr.	Equivalent Excess Rainfall Inches
1)	Statistical Analysis of Recorded Data	1945		
2)	Statistical Analysis of Recorded and Reconstituted Data	2310	710	3.7
3)	Rainfall-Runoff	2091	909	4.5
4)	Regional Regression	2369	912	4.5
5)	Weighted (2&4)	2320	745	3.70

Note: The values in this table are based on data collected between 1952 and 1978. See Appendix II for a preliminary checking of these values using the data through 1989.

TABLE 2

Recommended Design Flows - 1% Flood
Matadero-Barron-Adobe Creeks

		Peak	6-Hour	24-Hour	Area	
Adobe Creek @ City Limits	1	1558	1015	597	4.25	
Adobe Creek U/S Purissima Creek	2	2002	1330	774	5.53	
Adobe Creek @ Foothill Expressway	3	2748	1707	983	7.10	
Adobe Creek @ El Camino	4	2938	1910	1171	8.90	
Adobe Creek U/S Barron Creek	5	3080	2126	1375	10.84	
Barron Creek @ Foothill Expressway	6	762	403	222	1.76	
Barron Creek @ El Camino	7	829	492	305	2.56	
Barron Creek U/S Adobe Creek	5	834	552	362	3.09	
Adobe-Barron @ Bayshore Freeway	5	3914	2676	1736	13.93	
Matadero Creek U/S Deer Creek	8	1455	873	489	3.92	
Deer Creek U/S Matadero Creek	8	744	394	215	1.60	
Matadero Creek @ Foothill Expressway	8	2199	1260	704	5.52	
Matadero Creek @ El Camino	9	2359(2%-2012)	1486	912	7.55	U.S.G.S.
Matadero Creek @ Alma Street	10	2545(2%-2207)	1698	1113	9.42	
Matadero Creek @ Bayshore Freeway	11	2928	2166	1557	13.57	
Matadero-Barron-Adobe Inflow to Palo Alto Flood Basin	5,11	6842	4842	3291	27.50	

TABLE 3

Ten Year Flood Flows
Matadero-Barron-Adobe Creeks

		Peak	6-Hour	24-Hour	Area
Adobe Creek @ City Limits	1	821	615	316	4.25
Adobe Creek U/S Purissima Creek	2	1111	788	399	5.53
Adobe Creek @ Foothill Expressway	3	1433	977	490	7.10
Adobe Creek @ El Camino	4	1635	1161	633	8.90
Adobe Creek U/S Barron Creek	5	1822	1360	778	10.84
Barron Creek @ Foothill Expressway	6	323	199	95	1.76
Barron Creek @ El Camino	7	409	280	159	2.56
Barron Creek U/S Adobe Creek	5	455	334	199	3.09
Adobe-Barron @ Bayshore Freeway	5	2277	1694	977	13.93
Matadero Creek U/S Deer Creek	8	641	445	218	3.92
Deer Creek U/S Matadero Creek	8	320	198	93	1.60
Matadero Creek @ Foothill Expressway	8	961	639	311	5.52
Matadero Creek @ El Camino	9	1181	844	459	7.55
Matadero Creek @ Alma Street	10	1378	1037	608	9.42
Matadero Creek @ Bayshore Freeway	11	1794	1465	928	13.57
Matadero-Barron-Adobe Inflow to Palo Alto Flood Basin	5,11	4071	3158	1904	27.50

USE OF HYDROLOGIC PROCEDURES

During the 1960's, when the District was developing its hydrologic methods, much work was done by the District using the Stanford Watershed Model. Under the direction of Ray K. Linsley (Carrol Bradberry and Associates), the model was used to simulate precipitation and streamflow data for some watersheds in the County.

After an initial period of testing it was decided to abandon the Stanford Watershed Model (simulation) approach and adopt the statistical hydrology method that is in use today.

Some of the reasons for abandoning the Stanford Watershed Model were:

1. The results were deemed unusable because they were inconsistent with data obtained from other reliable sources.
2. Some design flows resulting from the model were lower than recorded data.

The USGS research into the use of deterministic, continuous models that are similar to the Stanford Watershed Model indicates that these tend to produce dampened, or lowered, flows or volumes for the larger, less frequent (near the 1% flood) events, and exaggerated flows or volumes for the more frequent floods (Ref. 20, 21).

The Hydrology Committee of the Water Resources Council determined in their 1981 research that less than 1% of all agencies in the U. S. use deterministic modeling (Stanford Watershed Model "SWM" or similar models) in their flood control studies.

Table 4 reproduces the results of that Water Resources Council study.

TABLE 4

USE OF HYDROLOGIC PROCEDURES
(in Percent)

Procedures	Federal Agencies	State Highway	Private Sector	Total
Statistical, unit hydrograph (SCVD)	73	58	75	69
Empirical Equations	24	38	17	26
Simulation (Linsley, Kraeger)	0	0	1	less than 1%
Other	3	4	7	4

Adapted from Table iii-2, U. S. Water Resources Council, Estimating Peak Flow Frequencies for Natural Ungaged Watersheds, 1981.

Our own investigation, summarized in Table 5, shows that none of the polled flood control agencies in California and elsewhere rely on the Stanford Watershed Model at the present time and there are no plans by them to use it for flood control design applications in the future. San Mateo County used the model at one time to determine the hydrology of the creeks draining the eastern slopes of the Santa Cruz Mountains. The results proved unsatisfactory near Highway 280 and were not used. As described above, in the late 1960's the Santa Clara County Flood Control and Water District used the technique in a contract with Carrol E. Bradberry & Associates, consulting engineers. The results were found to be inappropriate for flood control design (that is, they did not seem to fit with historical records) and were not used. In addition, Santa Barbara County used the SWM for flood forecasting and watershed management, but later abandoned it because of similar observations with regard to the SWM results compared to the historical record.

TABLE 5

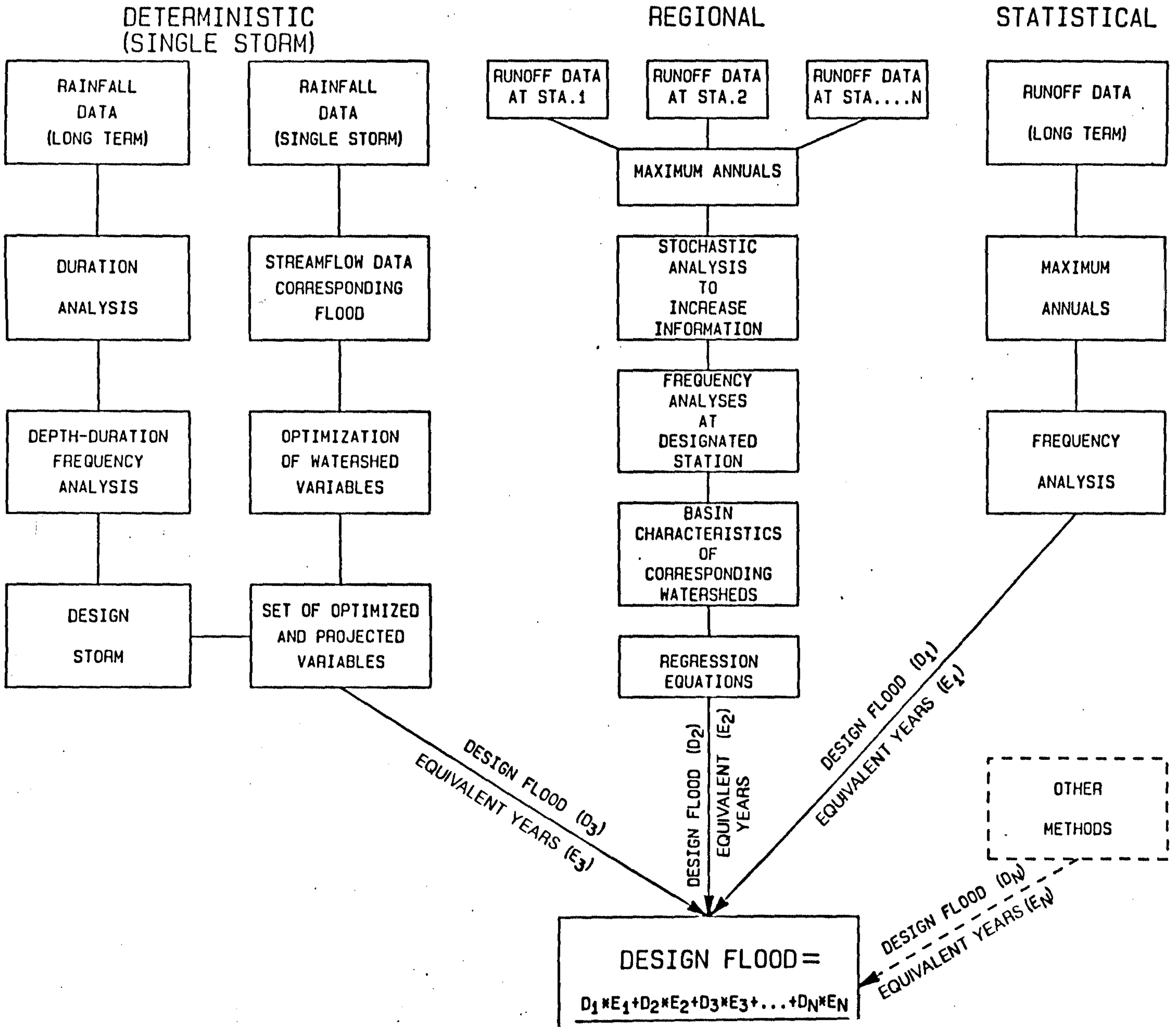
HYDROLOGIC METHODS USED BY FLOOD CONTROL AGENCIES IN CALIFORNIA (APRIL 1984)

Flood Control Agency	SCVWD METHOD or Similar
Los Angeles County	Yes
Alameda County	Yes
Contra Costa County	Yes
Marin County	Yes
Monterey County	Yes
Riverside County	Yes
San Bernardino County	Yes
Santa Barbara County	Yes
Santa Clara Valley Water (SCVWD)	Yes
San Diego County	Yes
San Mateo County	Yes
Soil Conservation Service	Yes
Corps of engineers	Yes

APPENDIX I

Diagram of Districts Hydrologic Method

DISTRICT METHOD



APPENDIX II

Analysis Of Streamflow Data From Matadero Creek Gaging Station (1952-1989)

The number of annual streamflow record at USGS gaging station # 1660 (Matadero Creek At El Camino) has increased from 23 years (1952-75) to 37 years (1952-89) since the 1978 update of hydrology methods and the calculation of design flows. This appendix contains two updated preliminary frequency analyses of the data covering the period between 1952 and 1989, using the Log Pearson Type III distribution. The first analysis assumes a regional coefficient of skewness (CS) equal to -0.4 and the other analysis assumes a regional CS equal to -0.6. The resultant 1% flood values of 2020 cfs and 1880 cfs respectively are obtained at the gaged location. These values are approximately equal to the original value of 1945 cfs at the same location (table 1), which makes us confident that the Matadero Creek design flood flows obtained in 1978 are still valid today.

Due to its close proximity to Matadero Creek, and due to the use of a similar hydrologic techniques, the original 1% design flood flow of 3100 cfs on Adobe Creek at the beginning of the project is valid today.

Attached are copies of this preliminary updated frequency analysis.

```
**TITLE CARD(S)**
TT   Matadero creek (USGS #1660) LOG PEARSON TYPE 3 ANALYSIS
TT
TT   C.E. NAHN 4/18/89

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS   1660    .130    -.60

**SYSTEMATIC EVENTS**
     37 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++



 FINAL RESULTS
-PLOTTING POSITIONS-  1660
******************************************************************
*.....EVENTS ANALYZED......*...........ORDERED EVENTS..........*
*                          *         WATER              WEIBULL  *
* MON DAY  YEAR  FLOW,CFS  *    RANK  YEAR   FLOW,CFS  PLOT POS *
*--------------------------*-------------------------------------*
*  12   6  1952      535.  *       1  1983     1500.     .0263  *
*   3  19  1954       26.  *       2  1973     1200.     .0526  *
*   1  18  1955      170.  *       3  1986     1030.     .0789  *
*  12  22  1955      854.  *       4  1956      854.     .1053  *
*   2  24  1957       28.  *       5  1969      792.     .1316  *
*   4   2  1958      672.  *       6  1967      765.     .1579  *
*   2  16  1959      340.  *       7  1974      713.     .1842  *
*   2   8  1960      139.  *       8  1982      691.     .2105  *
*  11  25  1960       45.  *       9  1978      683.     .2368  *
*   3   5  1962      365.  *      10  1958      672.     .2632  *
*   1  31  1963      641.  *      11  1963      641.     .2895  *
*   1  20  1964      223.  *      12  1980      594.     .3158  *
*   1   5  1965      219.  *      13  1971      576.     .3421  *
*  12  28  1965      311.  *      14  1953      535.     .3684  *
*   1  24  1967      765.  *      15  1968      490.     .3947  *
*   1  30  1968      490.  *      16  1975      405.     .4211  *
*   1  26  1969      792.  *      17  1988      405.     .4474  *
*   3   4  1970      363.  *      18  1987      388.     .4737  *
*  12  20  1970      576.  *      19  1962      365.     .5000  *
*  12  21  1971      246.  *      20  1970      363.     .5263  *
*   2  27  1973     1200.  *      21  1959      340.     .5526  *
*   1   3  1974      713.  *      22  1966      311.     .5789  *
*   3  21  1975      405.  *      23  1979      305.     .6053  *
*  10  10  1975       81.  *      24  1984      286.     .6316  *
*   1   2  1977      114.  *      25  1972      246.     .6579  *
*   1  16  1978      683.  *      26  1964      223.     .6842  *
*   1  14  1979      305.  *      27  1965      219.     .7105  *
*   2  19  1980      594.  *      28  1985      197.     .7368  *
*   1  27  1981      133.  *      29  1955      170.     .7632  *
*   3  31  1982      691.  *      30  1960      139.     .7895  *
*   1  21  1983     1500.  *      31  1981      133.     .8158  *
*  12  11  1983      286.  *      32  1977      114.     .8421  *
*   2   8  1985      197.  *      33  1976       81.     .8684  *
*   2  18  1986     1030.  *      34  1989       77.     .8947  *
*   2  13  1987      388.  *      35  1961       45.     .9211  *
*   1  17  1988      405.  *      36  1957       28.     .9474  *
*  11  23  1988       77.  *      37  1954       26.     .9737  *
******************************************************************
```

```
-OUTLIER TESTS  -
-----------------------------------------------------------------
LOW OUTLIER TEST
----------------

BASED ON  37 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.650

       0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF     22.2


----------------
HIGH OUTLIER TEST
----------------

BASED ON  37 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.650

      0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF    4358.

-----------------------------------------------------------------


-SKEW WEIGHTING -
-----------------------------------------------------------------
BASED ON  37 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =   .219
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =   .130
-----------------------------------------------------------------



 FINAL RESULTS
-FREQUENCY CURVE-  1660
*****************************************************************
*........FLOW,CFS........*              *...CONFIDENCE LIMITS...*
*            EXPECTED    * EXCEEDANCE   *                       *
*  COMPUTED  PROBABILITY * PROBABILITY  *  .05 LIMIT  .95 LIMIT *
*------------------------*--------------*-----------------------*
*     2410.      2650.   *     .002     *     4290.      1590.  *
*     2120.      2290.   *     .005     *     3670.      1420.  *
*     1880.      2010.   *     .010     *     3180.      1280.  *
*     1630.      1720.   *     .020     *     2680.      1130.  *
*     1370.      1430.   *     .040     *     2180.       967.  *
*     1010.      1040.   *     .100     *     1520.       736.  *
*      730.       742.   *     .200     *     1040.       546.  *
*      349.       349.   *     .500     *      462.       266.  *
*      141.       138.   *     .800     *      188.       100.  *
*       82.        78.   *     .900     *      115.        53.  *
*       51.        46.   *     .950     *       75.        30.  *
*       19.        15.   *     .990     *       31.         9.  *
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*
*   FREQUENCY CURVE STATISTICS    *     STATISTICS BASED ON     *
*---------------------------------*-----------------------------*
*  MEAN LOGARITHM         2.4926  *  HISTORIC EVENTS          0 *
*  STANDARD DEVIATION      .4327  *  HIGH OUTLIERS       0      *
*  COMPUTED SKEW         -.8983   *  LOW OUTLIERS        0      *
*  GENERALIZED SKEW      -.6000   *  ZERO OR MISSING     0      *
*  ADOPTED SKEW          -.7000   *  SYSTEMATIC EVENTS      37  *
*****************************************************************


++++++++++

END OF RUN
```

```
**TITLE CARD(S)**
TT   Matadero creek (USGS #1660) LOG PEARSON TYPE 3 ANALYSIS
TT
TT   C.E. NAHN 4/18/89

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS   1660    .130    -.40

**SYSTEMATIC EVENTS**
     37 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++


 FINAL RESULTS
-PLOTTING POSITIONS-  1660
*****************************************************************
*.....EVENTS ANALYZED......*...........ORDERED EVENTS..........*
*                          *          WATER               WEIBULL  *
* MON DAY  YEAR  FLOW,CFS  *    RANK  YEAR   FLOW,CFS  PLOT POS *
*--------------------------*-----------------------------------*
*  12   6  1952     535.   *      1   1983    1500.     .0263   *
*   3  19  1954      26.   *      2   1973    1200.     .0526   *
*   1  18  1955     170.   *      3   1986    1030.     .0789   *
*  12  22  1955     854.   *      4   1956     854.     .1053   *
*   2  24  1957      28.   *      5   1969     792.     .1316   *
*   4   2  1958     672.   *      6   1967     765.     .1579   *
*   2  16  1959     340.   *      7   1974     713.     .1842   *
*   2   8  1960     139.   *      8   1982     691.     .2105   *
*  11  25  1960      45.   *      9   1978     683.     .2368   *
*   3   5  1962     365.   *     10   1958     672.     .2632   *
*   1  31  1963     641.   *     11   1963     641.     .2895   *
*   1  20  1964     223.   *     12   1980     594.     .3158   *
*   1   5  1965     219.   *     13   1971     576.     .3421   *
*  12  28  1965     311.   *     14   1953     535.     .3684   *
*   1  24  1967     765.   *     15   1968     490.     .3947   *
*   1  30  1968     490.   *     16   1975     405.     .4211   *
*   1  26  1969     792.   *     17   1988     405.     .4474   *
*   3   4  1970     363.   *     18   1987     388.     .4737   *
*  12  20  1970     576.   *     19   1962     365.     .5000   *
*  12  21  1971     246.   *     20   1970     363.     .5263   *
*   2  27  1973    1200.   *     21   1959     340.     .5526   *
*   1   3  1974     713.   *     22   1966     311.     .5789   *
*   3  21  1975     405.   *     23   1979     305.     .6053   *
*  10  10  1975      81.   *     24   1984     286.     .6316   *
*   1   2  1977     114.   *     25   1972     246.     .6579   *
*   1  16  1978     683.   *     26   1964     223.     .6842   *
*   1  14  1979     305.   *     27   1965     219.     .7105   *
*   2  19  1980     594.   *     28   1985     197.     .7368   *
*   1  27  1981     133.   *     29   1955     170.     .7632   *
*   3  31  1982     691.   *     30   1960     139.     .7895   *
*   1  21  1983    1500.   *     31   1981     133.     .8158   *
*  12  11  1983     286.   *     32   1977     114.     .8421   *
*   2   8  1985     197.   *     33   1976      81.     .8684   *
*   2  18  1986    1030.   *     34   1989      77.     .8947   *
*   2  13  1987     388.   *     35   1961      45.     .9211   *
*   1  17  1988     405.   *     36   1957      28.     .9474   *
*  11  23  1988      77.   *     37   1954      26.     .9737   *
*****************************************************************
```

```
-OUTLIER TESTS  -
----------------------------------------------------------------
LOW OUTLIER TEST
----------------

BASED ON  37 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.650

       0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF     22.2


----------------
HIGH OUTLIER TEST
-----------------

BASED ON  37 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.650

      0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF    4358.

----------------------------------------------------------------


-SKEW WEIGHTING -
----------------------------------------------------------------
BASED ON  37 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =   .219
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =   .130
----------------------------------------------------------------



 FINAL RESULTS
-FREQUENCY CURVE-  1660
****************************************************************
*........FLOW,CFS........*             *...CONFIDENCE LIMITS...*
*             EXPECTED   * EXCEEDANCE  *                       *
*  COMPUTED  PROBABILITY * PROBABILITY *  .05 LIMIT  .95 LIMIT *
*------------------------*-------------*-----------------------*
*     2700.      3010.   *    .002     *     4910.      1750.  *
*     2320.      2540.   *    .005     *     4090.      1540.  *
*     2020.      2190.   *    .010     *     3470.      1370.  *
*     1730.      1840.   *    .020     *     2870.      1190.  *
*     1430.      1500.   *    .040     *     2280.      1000.  *
*     1030.      1060.   *    .100     *     1550.       747.  *
*      730.       743.   *    .200     *     1040.       546.  *
*      343.       343.   *    .500     *      454.       262.  *
*      140.       137.   *    .800     *      187.        99.  *
*       83.        78.   *    .900     *      115.        54.  *
*       52.        48.   *    .950     *       76.        31.  *
*       20.        16.   *    .990     *       33.        10.  *
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*
*   FREQUENCY CURVE STATISTICS   *     STATISTICS BASED ON     *
*--------------------------------*-----------------------------*
*  MEAN LOGARITHM        2.4926  *  HISTORIC EVENTS         0  *
*  STANDARD DEVIATION     .4327  *  HIGH OUTLIERS       0      *
*  COMPUTED SKEW         -.8983  *  LOW OUTLIERS        0      *
*  GENERALIZED SKEW      -.4000  *  ZERO OR MISSING     0      *
*  ADOPTED SKEW          -.6000  *  SYSTEMATIC EVENTS      37  *
****************************************************************


++++++++++

END OF RUN
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BIBLIOGRAPHY

1. Yevjevich, Simon, Review of Methods Used for Estimation of Floods In Santa Clara Valley; Santa Clara Valley Water District, September 1967.

2. Beard, James, Dawdy, Yevjevich & Grigg, Review of Basic Hydrology Methodology for Flood Control, Santa Clara Valley Water District, April 1976.

3. A. D. Saah, Hydrology Documentation For Northwest Flood Control Zone, Santa Clara Valley Water District, July 1976.

4. Carrol Bradberry & Associates, Synthesized Streamflow Data, Santa Clara County, 1964.

5. Carrol Bradberry & Associates, Hydrologic Atlas, Santa Clara County, 1964.

6. U. S. Water Resources Council, Guidelines for Determining Flood Flow Frequency, Bulletins 17 and 17B.

7. Saah, Talley and Sanchez, Development of Regional Regression Equations, Santa Clara Valley Water District (Draft Report), March 1976.

8. Saah, Watson, Urban Hydrology Methodology, Paper presented at the National Symposium on Urban Hydrology, Santa Clara Valley Water District, March 1976.

9. U. S. Army Corps of Engineers, HEC-1 Flood Hydrograph Package, The Hydrologic Engineering Center, California, 1973.

10. Beard, L. R., Statistical Methods in Hydrology, U. S. Army Corps of Engineers, Civil Works 1. P. CW151, 1962.

11. Linsley, Kreager Associates, Hydrologic Analysis of the Palo Alto Flood Basin, April 1984.

12. EPA - 60019-80-015, Users Manual For Hydrological Simulation Programs - FORTRAN (HSPF), April 1980.

13. U. S. Army Corps of Engineers, HEC Program 723-X6 - L2350, Regional Frequency Computations, 1972 Update.

14. V. T. Chow, Handbook of Applied Hydrology, 1964.

15. Langbein, W. B., Annual Floods and Partial Duration Series, Trans. W. G. W. Vol. 30, 1949.

16. Matalas, N. & B. Jacobs, A Correlation Procedure for Augmenting Hydrologic Data, U.S.G.S. Paper # 434 E, 1964.

17. Myron Feiring, Used of Correlation to Improve Estimates of the Mean and Variance, U. S. G. S. Paper 434C.

18. U. S. Army Corp of Engineers, HEC Program # 704-Gl - L202., Multiple Linear Regression.

19. Jennings and Benson, Frequency Curves for Annual Flood Series with Incomplete Data. U.S.G.S., 1969.

20. Wilbert O. Thomas Jr., An Evaluation of Flood Frequency Estimates Based on Rainfall/Runoff Modeling, Water Resources Bulletin, AWRA, April 1982.

21. Lichty and Liscum, A Rainfall-Runoff Modeling Procedure for Improving Estimates of T-Year Annual Flood For Small Drainage Basins. U.S.G.S. W.R.1. 78-7, August 1978.

22. Water Resources Council, Estimating Peak Flow Frequencies For Natural Ungaged Watersheds, A Proposed Nationwide Test, Hydrology Committee, 1981.

23. Astrue, Sutcliffe & McNeely, Report on Flooding and flood Related Damage January 1, to April 30, 1984, October

24. Salas, Yevjevich, Boas, Delleur, Schaake et. al., Lecture Notes for the Computer Workshop in Statistical Hydrology, Colorado State University, July 1978.

25. FEMA - 37, Flood Insurance Study, Guidelines and Specifications For Study Contractors, FEMA, September 1982.

26. W. R. C., A Unified National Program for Flood Plan Management, July 1976.

27. Department of Water Resources, Rainfall Analysis for Drainage Design, Bulletin #195, October 1976.

28. Other office reports, computations and computer printouts - available from District library.